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Environmental Impacts of the Use of Orimulsion®

Report to Congress on Phase 1 of the Orimulsion® Technology Assessment Program

Volume 1: Executive Summary, Report, and Appendix A

Foreword

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental probelms by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Managment Research Laboratory

EPA REVIEW NOTICE

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Environmental Impacts of the Use of Orimulsion®

Report to Congress on Phase 1 of the Orimulsion® Technology Assessment Program

Volume 1. Executive Summary, Basic Report, and Appendix A

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Abstract

Orimulsion, a bitumen-in-water emulsion produced in Venezuela, was evaluated to provide a better understanding of the potential environmental impacts associated with its use as a fuel. A series of pilot-scale tests were conducted at the U.S. Environmental Protection Agency's Environmental Research Center in Research Triangle Park, NC, to provide data on emissions of air pollutants from the combustion of Orimulsion 100 (the original formulation), Orimulsion 400 (a new formulation introduced in 1998), and a No. 6 (residual) fuel oil. These results, and results of full-scale tests reported in the technical literature, were evaluated to determine the potential air pollutant emissions and the ability of commercially available pollution control technologies to adequately reduce those emissions. Emissions of carbon monoxide (CO), oxides of nitrogen (NO_x), sulfur dioxide (SO_2), sulfur trioxide, particulate matter (PM), and organic and metal hazardous air pollutants (HAPs) were measured from each of these three fuels to provide a comparison between the "new" fuel (Orimulsion) and a fuel that has been commonly used in the U.S. (the No. 6 fuel oil). Results indicate that CO, NO_x, and PM emissions are likely to be nearly the same as those from the No. 6 fuel oil, that SO_2 emissions can increase if the fuel sulfur content increases, that the particles generated by Orimulsion 100 and 400 are likely to be smaller in diameter than those generated by No. 6 fuel oil, and that HAPs are also likely to be similar to those from No. 6 fuel oil. Both the full-scale results found in the literature and the pilot-scale results measured at EPA indicate that conventional air pollution control technologies can effectively reduce emissions to very low levels, depending upon the type of technology used and the desired emission levels. Because the bitumen in Orimulsion is heavier than water and due to the presence of a surfactant in the fuel, spills of Orimulsion are likely to be more difficult to contain and recover than are spills of heavy fuel oil, especially in fresh water. Additional study is needed before adequate containment and response approaches can be developed. Little, if any, work has been conducted by the fuel producer or the scientific community to address the remaining spill-related issues.

Preface

This report is the result of a request by the U.S. Congress to receive scientific information regarding the potential environmental impacts of the use of Orimulsion as a fuel. In the second half of the 1990s, there was considerable interest on the part of electric utilities in using Orimulsion, which was promoted as a low-cost fuel that could replace heavy fuel oil or coal. There were also many concerns raised by the environmental community regarding the environmental impact associated with switching to Orimulsion. In 1997, the U.S. Congress requested that the U.S. Environmental Protection Agency (EPA) conduct a study to evaluate the potential environmental impacts associated with the use of Orimulsion. EPA's Office of Research and Development provided funds to the National Risk Management Research Laboratory (NRMRL) to conduct this study, and a team of EPA experts in air pollution control, spill response, health effects, and environmental assessment was assembled to carry out the investigation. This report was prepared by EPA staff using data generated at EPA facilities as well as data collected from the general literature.

In 1998, Bituménes Orinoco (Bitor), the manufacturer of Orimulsion, changed the formulation of the fuel. The original fuel, renamed Orimulsion 100, was replaced with a new formulation named Orimulsion 400. Compared to the amount of information on Orimulsion 100, there is relatively little data on the performance of Orimulsion 400. While this report provides as much data as possible on the emissions and performance of Orimulsion 400, the bulk of the data are for the older formulation (Orimulsion 100). Although Orimulsion 100 is no longer produced, the results presented here are still believed to adequately describe the basic behavior of both formulations of Orimulsion. The key question to be addressed in this study is, "Is Orimulsion significantly different from other fossil fuels, and if so, how?" The differences between Orimulsion 100 and Orimulsion 400, as indicated both from the available data and the information provided by the manufacturer, are substantially smaller than the differences between Orimulsion and other fossil fuels. The report distinguishes between the two formulations where appropriate, but uses the generic term "Orimulsion" where such distinction is either unimportant or misleading. The recent reformulation is significant with respect to the surfactant used (which will affect spill toxicity) and the use of a magnesium-based additive (which will affect boiler tube deposition and particulate matter emissions). Other environmental issues appear to be impacted only to a minor degree by the change in formulation.

The emphasis of this report is on generation and control of air pollutants from the combustion of Orimulsion. Although there are other environmental issues associated with the use of Orimulsion, particularly spills of the fuel into water, EPA and NRMRL were advised on several occasions that questions related to air pollutant generation and control were the key unknowns associated with understanding the environmental impact potential of Orimulsion. The initial step in EPA's research activities was the convening of a workshop to discuss environmental issues related to Orimulsion use. This workshop, held February 8, 1998, concluded that there was a lack of information on particle size distribution and composition and on emissions and control of sulfur trioxide from Orimulsion combustion. The workshop also concluded that enough data existed to allow a comparative risk analysis for heavy fuel oil and Orimulsion, and therefore additional research in that area was not immediately required. The workshop noted that a lack of data existed describing the behavior, fate, and effects of Orimulsion spills in fresh water. However, the workshop concluded that investigations into these areas should be the responsibility of Bitor in the event they sought to market the fuel to users where spills into fresh water were possible. Considerable work has been conducted to quantify behavior, fate, and effects of Orimulsion in saltwater environments under the oversight of the International Orimulsion Working Group, of which Bitor is a member and the major source of funding. Thus this report has as its focus the generation and control of air pollutants, although other topics are also covered.

This focus was emphasized in the Orimulsion Technology Assessment Plan that was prepared to guide EPA's research efforts. This plan was reviewed and approved, with modifying comments, by a

panel of technical experts, mostly from outside the federal government. The only exception was one member from the U.S. Coast Guard. The Plan was then reviewed by the Office of Management and Budget (OMB), the U.S. Department of Energy, and the Office of Science and Technology Policy. EPA responded to comments made by each of these organizations and revised the Plan, which was approved by OMB on April 22, 1999.

The National Risk Management Research Laboratory was the lead organization for the study, and was chiefly responsible for preparation of Chapters 1-5 and 9-12. Robert E. Hall was the overall program lead, and C. Andrew Miller was the lead author of these chapters. Kevin Dreher of the National Health and Environmental Effects Research Laboratory prepared Chapter 6, on toxicity testing, with substantial assistance from Adriana Crain. Chapter 7, on spills, was prepared with assistance from Royal J. Nadeau of EPA's Office of Solid Waste and Emergency Response. Randall Wentsel of the National Center for Environmental Assessment prepared Chapter 8, on environmental assessment.

The conclusions stated in this report are scientific conclusions, and are not intended to provide guidance relative to regulatory requirements that may or may not apply to the use of Orimulsion.

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- Morten Thellefsen Nielsen, Technical University of Denmark, Lyngby, Denmark.

Many of the reports from which full-scale data were taken were provided by Nelson Garcia Tavel of Bitor America, Jason Miles of Bitor Europe, and independent consultant Ken Olen.

Nomenclature and Acronyms

APCS	air pollution control system
API	American Petroleum Institute
APPCD	Air Pollution Prevention and Control Division
ARD	Arizona road dust
ASTM	American Society for Testing and Materials
BALF	bronchoalveolar fluid
bbl	barrels, U.S. petroleum
BTEX	benzene, toluene, ethylene, and xylenes
Btu	British thermal unit
CAA	Clean Air Act
CAAAs	Clean Air Act Amendments of 1990
CARB	California Air Resources Board
CE	Combustion Engineering
CEM	continuous emission monitor
CO	carbon monoxide
CO_2	carbon dioxide
DAS	data acquisition system
DQI	data quality indicator
EDX	energy dispersive x-ray
ENEL	Italian Electricity Generating Board
EPA	Environmental Protection Agency
ESP	electrostatic precipitator
FETC	U.S. Department of Energy's Federal Energy Technology Center
FGD	flue gas desulfurization
FPL	Florida Power & Light Company
GIS	geographical information systems
HAP	hazardous air pollutant
HEPA	high efficiency particulate air
HFO	heavy fuel oil
HQ	health quotient
IOWG	International Orimulsion Working Group
IURE	inhalation unit risk estimate
LAPIO	low API oil
LDH	lactate dehydrogenase
LNB	low NO_x burner
LOEC	lowest observable effects concentration
LOEL	lowest observed effect level
LOI	loss on ignition
MACS	miniature acid-condensation system
MDL	method detection limit
MEI	maximum exposed individual
MIR	maximum individual risk
NCEA	National Center for Environmental Assessment
NHEERL	National Health and Environmental Effects Research Laboratory
NO	nitric oxide
NOEC	no observable effects concentration
NO_x	nitrogen oxides
NRC	National Research Council

Nomenclature and Acronyms (Continued)

NRMRL	National Risk Management Research Laboratory
NSPS	New Source Performance Standard
O_2	oxygen
OERR	Office of Emergency and Remedial Response
OFA	overfire air
ORD	Office of Research and Development
ORI 100	Orimulsion 100
ORI 400	Orimulsion 400
OSWER	Office of Solid Waste and Emergency Response
OTAP	Orimulsion Technology Assessment Plan
PAH	polycyclic aromatic hydrocarbon
PBS	Package Boiler Simulator
PC	pulverized coal
PDVSA	Petroléos de Venezuela, S.A.
PEA	performance evaluation audit
PM	particulate matter
$PM_{2.5}$	particulate matter smaller than 2.5 μm in aerodynamic diameter
PM_{10}	particulate matter smaller than 10 μm in aerodynamic diameter
ppm	parts per million
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
ROFA 6	residual oil fly ash (No. 6 fuel oil)
RSD	relative standard deviation
SASS	source assessment sampling system
SCR	selective catalytic reduction
SEM	scanning electron microscope
SMPS	scanning mobility particle sizer
SNCR	selective noncatalytic reduction
SO_2	sulfur dioxide
SO_3	sulfur trioxide
SVOC	semivolatile organic compound
TCLP	toxicity characteristic leaching potential
THC	total hydrocarbon
TSA	technical systems audit
VOC	volatile organic compound
VOST	volatile organic sampling train
WLFO	wet limestone forced oxidation
XRF	X-ray fluorescence

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